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The effect of the Asian financial crisis on the relationships among open macroeconomic factors for Asian countries

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This study investigates the effect of Asian financial crisis on the relationships among exchange rate volatility, export, import, and productivity for Taiwan, Korea, Malaysia, and Indonesia. Cointegration tests show no change for the long-run equilibrium relationship among these variables throughout the crisis. Granger causality finds that some exogeneity orderings alter from pre- to post-crisis periods for the countries considered. Impulse response functions (IRs) for the pre-crisis period demonstrate the primary importance of productivity, then second importance of export. For the post-crisis period, oscillatory paths around zero of the IRs imply an ambiguous finding for the direction of effect and relative exogeneity among variables studied. The variance decompositions in export for Taiwan, Korea and Malaysia, and in productivity for Malaysia and Indonesia did not change from the pre-crisis to the post-crisis era. However, most of the rest of the forecast error variances in variables were decomposed into their own innovation more proportional in the pre-crisis period than in the post-crisis period.

I. INTRODUCTION

Sparked from Thailand in July 1997, the Asian Financial Crisis (AFC hereafter) has brought severe turmoil to Asian countries. Except for China and Hong-Kong, the exchange rates have fluctuated dramatically since then.[1]

The high degree of volatility and uncertainty of most major exchange rates has been widespread concerned since the beginning of the floating regime in March 1973. As De Grauwe (1988) argued, 'the growth rate of international trade among industrial countries has declined by more than half since the inception of floating exchange rates'. The theoretical part describes that the increasing uncertainty caused by a higher exchange rate fluctuation, as the result of the AFC, will hurt the exports when firms are risk-averse. However, the other theoretical basis that 'higher volatility increases the potential gains from trade' is explained by Broll and Eckwert (1999), which supports a positive relationship between exchange rate volatility and export. Several studies within the last two decades have investigated this issue and most empirically found the evidence of a negative and statistically significant relationship between exchange rate volatility and export flows.[2] Nevertheless, among Keren and Rodrik (1986), Koray and Lastrapes (1989), Arize (1998), and Arize and Shwiff (1998), the significantly negative effect of exchange rate volatility on the volume of imports has been confirmed.

The depreciation of the currencies throughout the Asian region had caused a severe competition in international markets, especially, for those export-led countries. Thus, studies should also emphasize the relationship between exports and economic growth. Since the late 1970s, most studies support an export-led growth hypothesis, which in turn stimulates the policymakers to apply export-

[1] In order to maintain the pegged exchange rate to the US dollar, Hong-Kong introduced a huge jump in the short-run interest rate on 27 October, 1997.
[2] See: Arize (1995), Arize *et al.* (2000), Chowdhury (1993), Hassan and Tufte (1998) and Smith (1999).

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promotion policies for the development of economy in most of the developing countries. Traditional statistical methodologies have been used in former studies, such as Michaely (1977), Blassa (1978), Tyler (1981), Feder (1983) and Kavoussi (1984). However, the causal link between export flows and economic growth employing the causality test methodologies provided by Granger (1969) has been substantially applied after those former studies (e.g. June and Marshall, 1985; Chow 1987; Darrat, 1987; Hsiao, 1987; Ni *et al.* 1990; Serletis, 1992 and Ghartey, 1993). Nevertheless, use of the newly developed time-series methodologies, cointegration and vector error correction model (VECM), have further been attempted by Bahmani-Oskooee and Alse (1993), Oxley (1993) and Fung *et al.* (1994) for assessing the long-run equilibrium and the short-run causal relationship between export flow and economic growth. Among these, Fung *et al.* (1994) investigated the causal relationship among export, import and productivity in a multivariate framework, which expanded the two-variable case in order to avoid the bias due to the omission of the relevant variables. A critical finding suggested that export-promotion policies without consideration of the import flows may fail to achieve faster economic growth in both advanced countries and some newly industrializing countries (NICs).[3]

Since the exchange rate fluctuation had been significant during the period of the AFC in the Asian region, the examination of this study, based on the exchange rate stability, divides the test period into two sub-periods in order to investigate the impacts of this severe turmoil. Monthly data including two parts: (1) from December 1973 to June 1997 as the pre-crisis period and (2) from July 1997 to December 1999 as the post-crisis period, are employed. This paper firstly measures the exchange rate volatility followed the methods suggested by Chowdhury (1993) and Arize and Shwiff (1998). Secondly, it modifies the long-run equilibrium export and import demand models elaborated by Gotur (1985) to investigate the short-run causal and long-run equilibrium relationship among exchange rate volatility, export flows, import flows, and productivity in a multivariate framework.

This paper differs from those of previous studies in several ways. Firstly, being different from several previous exchange rate volatility measures, this paper constructs a time-varying moving average standard deviation of the exchange rate volatility to measure the long-run exchange rate uncertainty. Secondly, it considers two sub-periods to investigate the effects of the AFC. Finally, it constitutes a multivariate framework and incorporates a variety of newly developed methodologies (i.e., CI, GC, IR, and VD) to fully capture the short-run and long-run dynamic movements among variables considered.[4]

The organization of this paper is as follows: The following section specifies the models. Data are described in Section III. Section IV introduces the various methodologies and discusses the empirical results. Section V concludes this study.

II. MODEL SPECIFICATION

Traditional models, called import demand and export demand models, derived by Gotur (1985) can explain the long-run equilibrium of behavioural demand and supply functions for the volume of trade, exports or imports, in the flexible exchange rate regime. The reduced form of this model which describes the long-run relationship among real trade flows, the level of real activity (real output), competitiveness (relative price) and exchange rate volatility is presented as follows:

$$X_t = \alpha_0 + \alpha_1 y_t + \alpha_2 p_t + \alpha_3 \sigma_t + \varepsilon_t^x \tag{1}$$

$$M_t = \beta_0 + \beta_1 y_t^* + \beta_2 p_t^* + \beta_3 \sigma_t + \varepsilon_t^m \tag{2}$$

where X_t and M_t denote the logarithm of real exports and imports, respectively, y_t and y_t^* are the measure of the logarithm of domestic and foreign productivity in constant prices (real term). The logarithm of relative prices are proxied by the ratio of export prices of domestic country to those of its major trading partners (p_t) and the ratio of import prices to the domestic price level (p_t^*), respectively, all denominated in domestic currency. The notation of σ_t in both equations is the measure of exchange rate volatility.

Theoretically, the demand for exports and imports rises when foreign income and domestic income increase, respectively. Thus, both α_1 and β_1 are expected to be positive. On the other hand, the relative prices in both equations will have a negative impact on the volume of trade for both exports and imports, so α_2 and β_2 are expected to carry a negative sign. However, the relationship between trade flows and exchange rate volatility has been found ambiguous. If hedging is costly or impossible, the higher exchange rate volatility raises trade risk and thus decreases the foreign trade for risk-averse traders.

[3] As Fung *et al.* (1994) pointed out, when an export-led growth strategy is used in NICs, the relaxed foreign exchange constraint resulting from exports' earnings will enable these countries to import essential intermediary and capital goods for production that will further promote economic growth.

[4] The strength of this paper is that it employs: (1) the Johansen (1988, 1990, and 1994) five multivariate vector autoregression (VAR) models for the maximum likelihood cointegration test for long-run equilibrium relationship (CI); and (2) the Granger contemporary causality test (GC) for precedence relation; and (4) the methodologies of impulse response (IR) and variance decomposition (VD) for dynamic short run response among variables.

Whereas, De Grauwe (1988) theoretically elaborated on the phenomenon that the dominance of income effects over substitution effects can lead to a positive association of trade volume with volatility. Therefore, which direction of trade flows will be affected by the exchange rate volatility is a crucial issue to be explored (i.e., the sign of α_3 and β_3).

Assume there exists a generalized law of one price-GLOOP (purchasing power parity). Since the world income is the summation of domestic and foreign income, the Equations 1 and 2 can be rearranged as:

$$\sigma_t = f(X_t, M_t, Y) \tag{3}$$

The exchange rate volatility can be measured as a proxy for uncertainty in several ways.[5] Following Chowdhury (1993) and Arize and Shwiff (1998), this paper incorporates a time-varying proxy for σ_t, which is calculated by the moving average deviation of the growth rate of the nominal exchange rate, to measure the exchange rate volatility.[6,7]

$$\sigma_t = \left[(1/m) \sum_{i=1}^{m} (\log e_{t+i-1} - \log e_{t+i-2})^2 \right]^{0.5} \tag{4}$$

where $m = 3$ is taken for the seasonal consideration.

III. DATA

Monthly data collected from AREMOS of the Ministry of Education, Taiwan are used in this paper for the period from January 1973 to December 1999. The total amount of observation for each country is 324. In order to investigate the impact of the AFC, this paper uses the inception of the crisis, July 1997, as the divider to examine pre- and post-crisis dynamic relationship among exchange rate volatility, exports, imports, and economic activities. In comparison, sample countries considered are two from the four Asian little dragons (i.e. Taiwan and Korea) and the other two from the four Asian little tigers (i.e., Malaysia and Indonesia).[8] Data on exchange rates are nominal exchange rates from the standpoint of practical traders. The exchange rate uncertainty – the measure of risk – is constructed by the proxy of the moving-average standard deviation of the growth rate of exchange rate.

IV. METHODOLOGIES

A variety of newly developed methodologies are employed to fully investigate the effects of the AFC on the relationships among variables considered.

The paper first employs ADF tests (Dickey and Fuller, 1981) for the single unit root. In order to insure the 'stationarity' property for the higher order of integration, the test methods suggested by Dickey and Pantula (1987) is further employed for the multiple unit roots. As long as it is possible not to reject the null hypothesis that the various values of the ϕ_i are zero, the multiple unit roots, say r, continue towards the equation:

$$\Delta^r y_t = \phi_1 \Delta^{r-1} y_{t-1} + \phi_2 \Delta^{r-2} y_{t-1} + \phi_3 \Delta^{r-3} y_{t-1} + \cdots + \phi_r y_{t-1} + \varepsilon_t \tag{5}$$

Akaike's information criterion (AIC) is used to determine the optimal number of lags based on the 'principle of parsimony' since the estimation might be biased if the lag length is pre-designated without rigorous determination.

The results of the ADF tests for the single unit root and Dickey–Pantula tests for multiple unit roots for variables: exchange rate volatility, export, import, and industrial production of four countries considered are reported in Table 1.

From this table, it is observed that most variables in this empirical study are shown a non-stationary property in the level, which is consistent with all the previous studies. However, above level term (first and second differences), all variables are significant away from the unit-root hypothesis.

Various methods of estimating cointegration have been applied to capture the long-run equilibrium relationship among variables. Among those, Johanson methodology based on the likelihood ratio with non-standard asymptotic distributions involving integrals of Brownian motions is found to be the best method to proceed cointegration estimation by Gonzalo (1994).[9]

The elaborate works developed by Johansen (1988, 1990, 1994) are summarized into five VAR models with ECM, which are presented in the following forms:[10]

[5] See Pagan *et al.* (1983), Akhtar and Hilton (1984), Chowdhury (1993), Arize (1995), and Arize and Shwiff (1998).
[6] Koray and Lastrapes (1989) have shown that this measure captures the temporal variation in the absolute magnitude of changes in real exchange rates, and therefore exchange rate risk, over time.
[7] There has been an argument about the preference of using real or nominal exchange rate volatility to measure exchange rate uncertainty. Thursby and Thursby (1987) and Lastrapes and Koray (1990) empirically found similar results by using both terms. In this paper, only the nominal term is used since it is more intuitive for the practical traders.
[8] Asia's four little dragons are recognized as Taiwan, Korea, Singapore and Hong-Kong; whereas Asia's four little tigers include Malaysia, Indonesia, Thailand and the Philippines.
[9] Gonzalo (1994) compared several methods of estimating cointegration which include ordinary least squares, nonlinear least squares, maximum likelihood in an error correction model, principle components, and canonical correlations.
[10] The 1990 equation form is from Johansen and Juselius (1990).

Table 1. *Tests for the order of integration based on Dickey–Pantula Test*

Variables	$\tau_\tau[1]$	$\tau_\tau[2]$	$\tau_\tau[3]$
VT	−1.7645(4)	−5.5270(3)***	−12.7218(4)***
XT	−2.4086(4)	−12.6539(3)***	−11.4384(7)***
MT	−3.4775(5)**	−9.4157(4)***	−12.6965(7)***
YT	−1.7779(4)	−14.6102(3)***	−14.6102(3)***
VK	−1.7054(5)	−5.1976(4)***	−10.2338(7)***
XK	−4.1622(2)***	−13.4417(4)***	−11.8196(12)***
MK	−2.9232(4)	−13.0015(3)***	−10.7147(11)***
YK	−2.2243(4)	−7.4116(5)***	−13.2353(7)***
VM	−3.0401(4)	−11.8179(5)***	−9.8310(11)***
XM	−3.2677(5)*	−7.6488(5)***	−11.3302(11)***
MM	−2.3959(5)	−7.3524(5)***	−10.9115(7)***
YM	−3.4836(2)	−9.0979(6)***	−12.4660(12)***
VI	−2.6316(2)	−11.2984(1)***	−10.5314(6)***
XI	−3.6599(5)**	−10.6317(4)***	−10.5158(11)***
MI	−2.7007(5)	−9.7589(5)***	−13.4891(7)***
YI	−2.4527(6)	−9.0242(5)***	−8.2541(12)***

Notes: 1. Abbreviations: T for Taiwan; K for Korea; M for Malaysia; I for Indonesia; V for exchange rate volatility; X for export; M for import and Y for economic activity.
2. $\tau_\tau[1]$: test for single unit root; $\tau_\tau[2]$: test for two unit roots; $\tau_\tau[3]$: test for three unit roots.
3. The numbers in the parentheses are lag length based on Akaike information criterion (AIC).
4. All the ADF tests consider the drift term and trend thus, τ_τ-statistic is used.
5. The critical values used are from MacKinnon (1991) table. The 1%, 5% and 10% critical values are −3.9742, −3.4180 and −3.1313, respectively.
6. The symbol ***, **, *, represent the significance at 1%, 5% and 10% levels, respectively.

$$H_0(r): \Delta X_t = \Gamma_1 \Delta X_{t-1} + \cdots + \Gamma_{k-1}\Delta X_{t-(k-1)} + \alpha\beta' X_{t-1} + \Psi D_t + \varepsilon_t \quad (1988) \tag{6}$$

$$H_1^*(r): \Delta X_t = \Gamma_1 \Delta X_{t-1} + \cdots + \Gamma_{k-1}\Delta X_{t-(k-1)} + \alpha(\beta', \beta_0)(X'_{t-1}, 1)' + \Psi D_t + \varepsilon_t \quad (1990) \tag{7}$$

$$H_1(r): \Delta X_t = \Gamma_1 \Delta X_{t-1} + \cdots + \Gamma_{k-1}\Delta X_{t-(k-1)} + \alpha\beta' X_{t-1} + \mu_0 + \Psi D_t + \varepsilon_t \quad (1990) \tag{8}$$

$$H_2^*(r): \Delta X_t = \Gamma_1 \Delta X_{t-1} + \cdots + \Gamma_{k-1}\Delta X_{t-(k-1)} + \alpha(\beta', \beta_1)(X'_{t-1}, t)'\mu_0 + \Psi D_t + \varepsilon_t \quad (1994) \tag{9}$$

$$H_2(r): \Delta X_t = \Gamma_1 \Delta X_{t-1} + \cdots + \Gamma_{k-1}\Delta X_{t-(k-1)} + \alpha\beta' X_{t-1} + \mu_0 + \mu_1 t + \Psi D_t + \varepsilon_t \quad (1994) \tag{10}$$

To analyse the deterministic term, Johansen decomposed the parameters μ_0 and μ_1 in the directions of α and $\alpha_\perp$ as $\mu_i = \alpha\beta_i + \alpha_\perp\gamma_i$, thus we have $\beta_i = \beta(\alpha'\alpha)^{-1}\alpha'\mu_i$ and $\gamma_i = (\alpha'_\perp\alpha_\perp)^{-1}\alpha'_\perp\mu_i$. The nested sub-models of the general model of null hypothesis $\Pi = \alpha\beta'$ are, therefore, defined as:

$$H_0(r):\; Y = 0$$

$$H_1^*(r):\; Y = \alpha\beta_0$$

$$H_1(r):\; Y = \alpha\beta_0 + \alpha_\perp\gamma_0$$

$$H_2^*(r):\; Y = \alpha\beta_0 + \alpha_\perp\gamma_0 + \alpha\beta_1 t$$

$$H_2(r):\; Y = \alpha\beta_0 + \alpha_\perp\gamma_0 + (\alpha\beta_1 + \alpha_\perp\gamma_1)t$$

Johansen (1994) emphasized the role of the deterministic term, $Y = \mu_0 + \mu_1 t$, which includes constant and linear terms in the Gaussian VAR. A decision procedure, following Nieh and Lee (2000) among the hypotheses $H(r)$ and $H^*(r)$ for five different models is presented in the following procedure:[11]

$$\begin{aligned} H_0(0) &\to H_1^*(0) \to H_1(0) \to H_2^*(0) \to H_2(0) \to H_0(1) \\ &\to H_1^*(1) \to H_1(1) \to H_2^*(1) \to H_2(1) \to \cdots \\ &\to \cdots \to H_0(p-1) \to H_1^*(p-1) \to H_1(p-1) \\ &\to H_2^*(p-1) \to H_2(p-1) \end{aligned}$$

The empirical findings for the long-run relationship with the consideration of a linear trend and a quadratic trend among exchange rate volatility, export, import and productivity for Asian four countries are summarized in Table 2a for pre-crisis and Table 2b for post-crisis.

The similar results are found for both periods that with the exception of Malaysia in which the four variables show no cointegrated relationship, variables considered all hold long-run equilibrium relationships in the other three countries (i.e., Taiwan, Korea and Indonesia). For both pre- and post-crisis periods, exchange rate volatility, export, import and productivity share long-run common trends with one cointegrating rank in Taiwan and Indonesia, and two cointegrating ranks in Korea. The appropriate Johansen model for all the long-run relationships among these four variables is revealed to be the one presenting no linear trend and quadratic trend (first model as developed in Johansen, 1988). The overall conclusion describes that the Asian financial crisis does not significantly affect the long-run equilibrium relationship among exchange rate volatility, export, import and productivity for all the Asian countries considered in this paper.

[11] Johansen (1992, 1994) developed a testing procedure based on the ideas developed by Pantula (1989) to determine the number of cointegrating rank in the presence of linear trend (Johansen, 1992) and quadratic trend (Johansen, 1994).

Table 2a. *Determination of cointegration rank in the presence of a linear trend and a quadratic trend (pre-crisis case).*

Rank	$T_0(r)$	$C_0(5\%)$	$T_1^*(r)$	$C_1^*(5\%)$	$T_1(r)$	$C_1(5\%)$	$T_2^*(r)$	$C_2^*(5\%)$	$T_2(r)$	$C_2(5\%)$
1. Taiwan										
$r=0$	56.83	39.89	85.65	53.12	66.22	47.21	74.29	62.99	71.06	54.64
$r \leqslant 1$	**29.07**	34.91	40.68	34.91	31.71	29.68	39.15	42.44	38.1155	34.55
$r \leqslant 2$	8.60	12.53	16.45	19.96	8.19	15.41	15.55	25.32	14.56	18.17
$r \leqslant 3$	0.08	3.84	5.611	9.24	1.99	3.76	6.13	12.25	5.83	3.74
AIC	4		4		4		4		4	
2. Korea										
$r=0$	130.07	39.89	161.74	53.12	100.64	47.21	115.22	62.99	103.20	54.64
$r \leqslant 1$	54.433	34.91	80.90	34.91	50.100	29.68	59.18	42.44	47.31	34.55
$r \leqslant 2$	**8.01**	12.53	34.06	19.96	19.557	15.41	27.31	25.32	17.82	18.17
$r \leqslant 3$	0.48	3.84	7.08	9.24	7.08	3.76	7.30	12.25	5.76	3.74
AIC	4		4		4		4		4	
3. Malaysia										
$r=0$	**33.52**	39.89	49.59	53.12	32.03	47.21	53.68	62.99	52.25	54.64
$r \leqslant 1$	13.71	34.91	27.82	34.91	15.32	29.68	26.11	42.44	24.73	34.55
$r \leqslant 2$	4.61	12.53	13.18	19.96	5.83	15.41	14.85	25.32	14.70	18.17
$r \leqslant 3$	0.00	3.84	4.16	9.24	0.07	3.76	5.56	12.25	5.56	3.74
AIC	5		5		5		5		5	
4. Indonesia										
$r=0$	69.06	39.89	77.69	53.12	56.94	47.21	84.98	62.99	81.47	54.64
$r \leqslant 1$	**31.91**	34.91	40.44	34.91	26.42	29.68	43.07	42.44	41.26	34.55
$r \leqslant 2$	11.59	12.53	19.02	19.96	6.89	15.41	20.16	25.32	19.89	18.17
$r \leqslant 3$	0.19	3.84	6.05	9.24	0.06	3.76	6.98	12.25	6.90	3.74
AIC	4		4		4		5		5	

Notes: 1. Countries investigated and Taiwan, Korea, Malaysia and Indonesia
2. $T_0(r)$, $T_1^*(r)$, $T_1(r)$, $T_2^*(r)$ and $T_2(r)$ denote the likelihood ratio test statistics for the null of $H(r)$ versus the alternative of $H(p)$, which include all the cases with or without the linear trend and quadratic trend.
3. The determining procedure is to select from left to right and top to bottom and decide to reject a hypothesis if all hypotheses with smaller number are also rejected.
4. $C_0(5\%)$, $C_1^*(5\%)$, $C_1(5\%)$, $C_2^*(5\%)$, $C_2(5\%)$ denote 95% critical value from Table-0, Table-1*, Table-1, Table-2* and Table-2 of Osterwald–Lenum (1992)
5. The bold number with underline indicates the selection of the rank in the presence of linear trend and quadratic trend.
6. VAR length is selected based on the smallest number of AIC (Akaike's Information Criterion).

Table 2b. *Determination of cointegration rank in the presence of a linear trend and a quadratic trend (post-crisis case).*

Rank	$T_0(r)$	$C_0(5\%)$	$T_1^*(r)$	$C_1^*(5\%)$	$T_1(r)$	$C_1(5\%)$	$T_2^*(r)$	$C_2^*(5\%)$	$T_2(r)$	$C_2(5\%)$
1. Taiwan										
$r=0$	60.44	39.89	79.51	53.12	76.44	47.21	127.91	62.99	124.66	54.64
$r \leqslant 1$	**14.84**	34.91	28.36	34.91	25.30	29.68	59.62	42.44	57.55	34.55
$r \leqslant 2$	5.12	12.53	6.83	19.96	3.87	15.41	12.58	25.32	10.54	18.17
$r \leqslant 3$	1.27	3.84	2.98	9.24	0.57	3.76	2.10	12.25	0.35	3.74
AIC	4		4		4		4		4	
2. Korea										
$r=0$	90.22	39.89	115.46	53.12	110.59	47.21	173.10	62.99	156.31	54.64
$r \leqslant 1$	47.12	34.91	57.15	34.91	52.68	29.68	83.75	42.44	66.98	34.55
$r \leqslant 2$	**11.89**	12.53	20.44	19.96	16.19	15.41	32.20	25.32	32.02	18.17
$r \leqslant 3$	3.78	3.84	4.65	9.24	0.49	3.76	13.74	12.25	13.66	3.74
AIC	4		4		4		4		4	
3. Malaysia										
$r=0$	**31.48**	39.89	66.24	53.12	63.83	47.21	102.96	62.99	92.49	54.64
$r \leqslant 1$	12.94	34.91	27.62	34.91	25.27	29.68	57.10	42.44	47.31	34.55
$r \leqslant 2$	2.25	12.53	9.15	19.96	6.85	15.41	24.60	25.32	17.20	18.17
$r \leqslant 3$	0.44	3.84	1.74	9.24	0.12	3.76	6.51	12.25	0.26	3.74
AIC	5		5		5		5		5	
4. Indonesia										
$r=0$	49.74	39.89	70.38	53.12	63.45	47.21	78.18	62.99	71.74	54.64
$r \leqslant 1$	**26.27**	34.91	39.88	34.91	32.95	29.68	47.59	42.44	41.55	34.55
$r \leqslant 2$	12.39	12.53	16.57	19.96	10.84	15.41	22.80	25.32	18.41	18.17
$r \leqslant 3$	4.81	3.84	6.23	9.24	0.74	3.76	7.23	12.25	3.22	3.74
AIC	4		4		4		5		4	

As Granger (1988) points out, if there exists a cointegration vector among variables, there must be causal relation among these variables at least in one direction.[12] Considering two series, A_t, and B_t, the models explained in the form of Granger (1969) is as follows:

$$A_t = c + \sum_{i=1}^{k} \alpha_{1i} A_{t-i} + \sum_{i=1}^{k} \beta_{1i} B_{t-i} + \mu_{at} \tag{11}$$

$$B_t = c + \sum_{i=1}^{k} \alpha_{2i} B_{t-i} + \sum_{i=1}^{k} \beta_{2i} A_{t-i} + \mu_{bt} \tag{12}$$

where k is the lag length selected by AIC. The series B_t fails to Granger cause A_t if $\beta_{1i} = 0$ $(i = 1, 2, 3, \ldots, k)$ and the series A_t fails to cause B_t if $\beta_{2i} = 0$.

Table 3a represents the results of the GC test for the pre-crisis period. Based on the 5% significant level, export precedes output and output precedes import for Taiwan, and thus, the relative exogeneity is ordered as export, output, import and exchange rate volatility (i.e., X, Y, M and V). This study also observes that output precedes export and export precedes import for Korea. Therefore, the exogenous ordering is Y, X, V and M for Korea. For both Malaysia and Indonesia, the orderings are Y, X, M and V. On the other hand, the results for the post-crisis represented in Table 3b show different exogeneity orderings. The orderings are X, M, Y and V for Taiwan and Korea, X, Y, M and V for Malaysia, and M, X, Y and V for Indonesia.

The summary of the results of the GC test for the ordering among four open macroeconomic factors for each country considered are represented as follows:

	Pre-crisis	Post-crisis
Taiwan	$X \rightarrow Y \rightarrow M \rightarrow V$	$V \rightarrow X \rightarrow Y \rightarrow M$
Korea	$Y \rightarrow X \rightarrow V \rightarrow M$	$V \rightarrow X \rightarrow Y \rightarrow M$
Malaysia	$Y \rightarrow X \rightarrow M \rightarrow V$	$Y \rightarrow X \rightarrow V \rightarrow M$
Indonesia	$Y \rightarrow X \rightarrow M \rightarrow V$	$V \rightarrow Y \rightarrow M \rightarrow X$

A significant observation is that, from pre- to post-crisis periods, the productivity from the relatively exogenous position becomes more endogenous and the exchange rate volatility becomes relatively exogenous for Taiwan, Korea and Indonesia; whereas, the exogeneity ordering does not change too much for Malaysia.

The more recent researches have largely applied the Impulse Response Functions (IR) and Variance Decompositions (VD) to conquer the difficulty of interpreting the estimated coefficients of a VAR model. An IR traces the response of one of the innovations on current and future values of the endogenous variables to a one standard deviation shock. This shock to a variable directly affects itself, and is also transmitted to all of the endogenous variables through the dynamic structure of the VAR. On the other hand, VD decomposes Forecast Error Variance (FEV) in an endogenous variable into percentage shocks to its own and other endogenous variables in the VAR, which in turn offers information about the relative importance (exogeneity ordering) of each random innovation to the variables.

Following Sims (1980, 1986) and Hamilton (1994), the reduced form of the structure VAR model: $Bx_t = \Gamma_0 + \Gamma_1 x_{t-1} + \varepsilon_t$, can be transformed to a four-dimension standard form: $x_t = A_0 + A_1 x_{t-1} + e_t$, where Γ_0 and $A_0 = B^{-1}\Gamma_0$ are 4×1 vector of constants; Γ_1, $A_1 = B^{-1}\Gamma_1$ and the back operator B are 4×4 matrices; the white-noise, ε_t and the disturbance $e_t = B^{-1}\varepsilon_t$ are 4×1 vectors.

For further derivation, we obtain a vector moving average (VMA) representation:

$$x_t = \mu + \sum_{i=0}^{\infty} A_1^i e_{t-i} \quad \left[\text{i.e., } x_t = (I + A_1 + \cdots + A_1^n) A_0 + \sum_{i=0}^{n} A_1^i e_{t-i} + A_1^{n+1} x_{t-n-1} \right]$$

In order to transfer the model to be expressed in the form of white-noise disturbance, this study finally reaches the form as following expression:

$$x_t = \mu + \sum_{i=0}^{\infty} \phi_{jk}(i) \varepsilon_{t-i} \tag{13}$$

where μ' is a 4×1 vector of constants and elements of $\phi_{jk}(i)$, a 4×4 matrix with $\phi_{jk}(0) = I_4$, are the 'impact multipliers', which examine the interaction over the entire path of volatility, export, import and productivity sequences. Equation 13 is the so-called impulse response function.

If the disturbance at all lags, ε_{t-i}, are absolute contemporaneously uncorrelated, the percentage of the FEV that occurs in the VAR, can be easily found and then judge the relative exogeneity of all the presumed endogenous variables. However, it is not always the case. Researchers thus applied Choleski decomposition (i.e., multiply disturbance term, ε_{t-i} by a 4×4 lower triangular matrix V, where $VV' = I_4$) to construct a VMA representation with disturbance process that is orthogonal contemporaneously at all lags. Assume the VMA representation: $x_t = \alpha' + \sum_{i=0}^{\infty} C_i \varepsilon_{t-i}$, where C_i is a 4×4 matrix with $C_0 = I_4$. The

[12]The pairwise Granger Causality test is actually employed to examine the 'precedence', not causality, between two variables.

Table 3a. *Pairwise Granger causality among exchange rates volatility, export, import and output for Asia four countries* (*pre-crisis case*).

Country	Taiwan(6)	Korea(5)	Malaysia(4)	Indonesia(6)
$V \Rightarrow X$	0.6604	1.2568	1.5894	0.9214
$X \Rightarrow V$	2.3951*	1.2380	1.2371	0.9919
$V \Rightarrow M$	0.7810	2.7670*	0.8310	2.0382
$M \Rightarrow V$	1.8167	0.7237	0.8660	0.4854
$V \Rightarrow Y$	1.3298	0.5604	0.3448	0.5604
$Y \Rightarrow V$	2.5728*	1.3671	1.3396	3.2039**
$X \Rightarrow M$	1.9996	4.7562***	2.5285*	3.7474**
$M \Rightarrow X$	1.8353	2.4310*	1.5250	1.4746
$X \Rightarrow Y$	3.5907**	0.9353	1.2841	1.7035
$Y \Rightarrow X$	2.5054*	5.9107***	2.3716*	1.7944
$M \Rightarrow Y$	2.5386*	2.6331*	0.6468	2.3381*
$Y \Rightarrow M$	3.7697**	3.3084*	2.4391*	2.7628*

Notes: 1. The 1%, 5%, and 10% critical values for F-statistic with d.o.f. of 2 (for numerator $n1 = 2$) and 292 (for denominator $n2 = 294–2$) are 4.61, 3.00, and 2.30.
2. The symbol ***, **, and *, represent the significant at 1%, 5%, and 10% levels, respectively.
3. Numbers within the parentheses are the lag length based on AIC for the 'principle of parsimony'.

Table 3a. *Pairwise Granger causality among exchange rates volatility, export, import and output for Asia four countries* (*post-crisis case*).

Country	Taiwan(6)	Korea(5)	Malaysia(4)	Indonesia(6)
$V \Rightarrow X$	0.0382	0.7232	0.8519	2.2874
$X \Rightarrow V$	0.4917	0.1413	2.6352*	0.0038
$V \Rightarrow M$	2.4602	2.3399	1.8382	3.3674**
$M \Rightarrow V$	0.3208	2.6410*	0.9576	1.2168
$V \Rightarrow Y$	2.7507*	7.3038***	0.0934	6.0633**
$Y \Rightarrow V$	2.6864*	1.3506	4.0832**	0.4185
$X \Rightarrow M$	0.0443	2.6498*	1.6080	0.3941
$M \Rightarrow X$	0.48333	0.3190	1.5370	1.5547
$X \Rightarrow Y$	1.8395	5.7776**	3.2393*	0.1253
$Y \Rightarrow X$	0.0272	1.0514	3.9155**	1.6042
$M \Rightarrow Y$	0.1316	0.7619	0.6304	0.0997
$Y \Rightarrow M$	2.5962*	1.4198	0.2999	0.1665

Notes: 1. The 1%, 5%, and 10% critical values for F-statistic with d.o.f. of 2 (for numerator $n1 = 2$) and 28 (for denominator $n2 = 30–2$) are 5.45, 3.34, and 2.50.
2. The symbol ***, **, and *, represent the significant at 1%, 5%, and 10% levels, respectively.
3. Numbers within the parentheses are the lag length based on AIC for the 'principle of parsimony'.

transformation for this VMA in terms of orthogonal innovations at all lags is given by

$$x_t = \alpha' + \sum_{i=0}^{\infty} c_i V V' \varepsilon_{t-i} = \alpha' \sum_{i=0}^{\infty} D_i \mu_{t-i} \qquad (14)$$

where $D_i = C_i V$ and $\mu_{t-i} = V' \varepsilon_{t-i}$.

From Equation 14, the k-step ahead forecast error of x_t is given by:

$$x_t - \hat{E}_{t-k} x_i = D_0 \mu_T + D_1 \mu_{t-1} + \cdots + D_{k-1} \mu_{t-k+1} \qquad (15)$$

where $\hat{E}_{t-k} x_t = D[x_t | x_{t-k},\ x_{t-k-a},\ x_{t-k-2}, \ldots]$, implies that utilizing all the information set at period $t-k$ to forecast present value of x_t. The corresponding variance–covariance matrix of this k-step ahead forecast error is expressed as follows:

$$\begin{aligned} E(x_t - \hat{E}_{t-k} x_t)\,(x_t - \hat{E}_{t-k} x_t)' &= D_0 E(\mu_t \mu_t') D_0' + D_1 E(\mu_t \mu_t') D' + \cdots \\ &\quad + D_{k-1} E(\mu_t \mu_t') D_{k-1}' \qquad (16) \end{aligned}$$

As King *et al.* (1991) and Zhou (1996) point out that as there is more than one common trend in a model, different ordering of variables may significantly affect the results of the IR and VD if the common trends are not absolutely uncorrelated. In this paper, the presumed exogenous orderings are adopted from the previous findings of the Granger causality tests.[13]

Results of the IR and VD are exhibited in Fig. 1 to 2 and Table 4, respectively, using '*a*' representing for pre-crisis and '*b*' for post-crisis.

From Fig. 1a to Fig. 1d, the IRs for the pre-crisis period demonstrate that the productivity has severe effect on other variables, especially on export, import and itself, for all four Asia countries considered. The response of export, import and productivity to productivity's shock is not only significant under a short-run, but also a long-run situation. Export's shock plays a secondarily important role, which affects the volume of export and import for countries except Korea. The shock from export in Taiwan even significantly affects the level of productivity. The import's shock has similar impacts on itself for all the countries considered. It declines after the first month, rebounds after the second month, reaches the local maximum at the third month, and then dampens thereafter. A surprising finding is that the shock from exchange rate volatility does not exhibit any significant effect to other three variables before crisis. Exchange rate volatility's shock merely affects itself in the short-run and dies out gradually. On the contrary, the IRs from Fig 2a to Fig 2d manifest the dynamic effects among variables for the post-crisis period. Oscillatory paths around zero are revealed for most of the cases, which assert an ambiguous finding for the direction of effect and the relative importance (exogeneity) among these variables.

The VDs are generated by disturbing one standard deviation of each variable in the estimated system. Given this disturbance, the FEV of any variable is decomposed into proportion attributed to each of the random shocks. From Table 4, it is observed that among variables considered, the VD in export for Taiwan, Korea and Malaysia, and in productivity for Malaysia and Indonesia do not change from pre-crisis to post-crisis era. For both periods, the FEVs in export for Taiwan and in productivity for Malaysia and Indonesia are all accounted for by their own innovations near 100%. Whereas, the FEV in export for Korea are decomposed into its own innovation about one-fifth and into productivity about 15%. The FEV in export for Malaysia are accounted for by its own innovation about two-thirds and by productivity about one-third. On the other hand, the rest of the FEVs are all changed after the severe turmoil. The results show that most of the rest of the FEVs in variables are decomposed into their own innovation more proportional in the pre-crisis period than the post-crisis period. For example, the FEVs in exchange rate volatility for all four countries are accounted for by their own shocks all near 100% before crisis. However, the percentage effect of their own shocks shrinks into half for Taiwan and Korea, decreases to one-third for Indonesia, and even vanishes for Malaysia after the crisis.

Table 4. *Variance decomposition* (*% of FEVs change from pre- to post-crisis*)

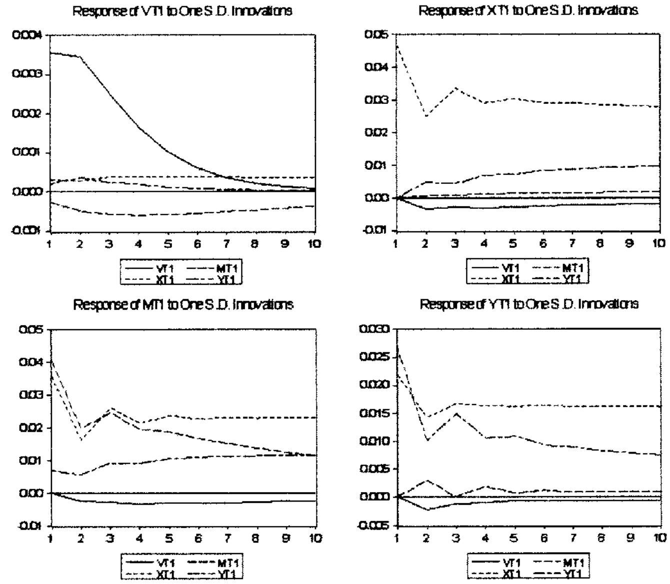
	V	*X*	*M*	*Y*
Taiwan				
V	1 → 45	0 → 10	0 → 25	0 → 20
X	**0 → 0**	**100 → 90**	**0 → 10**	**0 → 0**
M	0 → 0	50 → 60	50 → 20	50 → 20
Y	0 → 10	50 → 50	0 → 10	50 → 30
Korea				
V	100 → 70	0 → 15	0 → 0	0 → 15
X	**0 → 5**	**85 → 80**	**0 → 0**	**15 → 15**
M	0 → 25	15 → 45	75 → 0	10 → 30
Y	0 → 15	0 → 40	0 → 25	100 → 20
Malaysia				
V	100 → 20	0 → 40	0 → 20	0 → 20
X	**0 → 0**	**70 → 70**	**0 → 10**	**30 → 20**
M	0 → 0	15 → 10	85 → 40	0 → 50
Y	**0 → 0**	**0 → 0**	**0 → 10**	**100 → 100**
Indonesia				
V	100 → 30	0 → 10	0 → 35	0 → 25
X	0 → 5	90 → 50	10 → 20	0 → 25
M	0 → 10	15 → 0	85 → 0	0 → 90
Y	**0 → 0**	**0 → 0**	**0 → 0**	**100 → 100**

Notes: 1. Exogeneity orderings for pre-crisis are *X*, *Y*, *M* and *V* for Taiwan, *Y*, *X*, *V* and *M* for Korea, and *Y*, *X*, *M* and *V* for both Malaysia and Indonesia. Whereas, for post-crisis are *X*, *M*, *V* and *Y* for Taiwan and Korea, *X*, *Y*, *M* and *V* for Malaysia, and *M*, *X*, *V* and *Y* for Indonesia.
2. The percentages of FEVs are selected a quarter after the beginning of each sub-period.

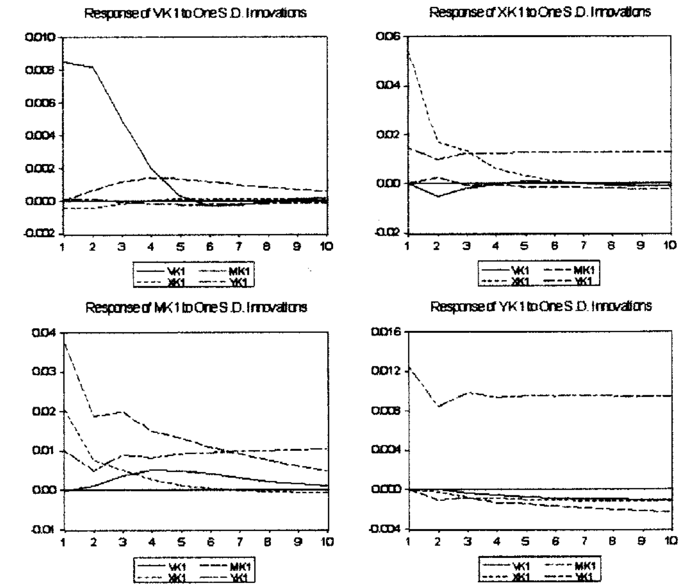
V. CONCLUSION

This study profoundly investigates the pre- and post-AFC effects on the relationships among exchange rate volatility, export, import and productivity for Taiwan, Korea, Malaysia and Indonesia. The overall conclusion from co-integration test proves that the AFC did not significantly

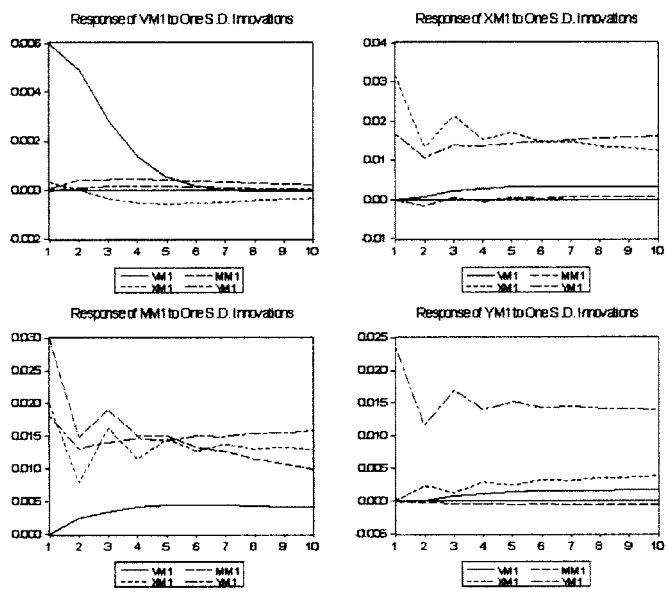
[13] The relative exogenity for the pre-crisis period is ordered as *X*, *Y*, *M* and *V* for Taiwan, *Y*, *X*, *V* and *M* for Korea, and *Y*, *X*, *M* and *V* for both Malaysia and Indonesia. Whereas, it is ordered as *V*, *X*, *Y* and *M* for both Taiwan and Korea, *Y*, *X*, *V* and *M* for Malaysia, and *V*, *Y*, *M*, and *X* for Indonesia for post-crisis period.



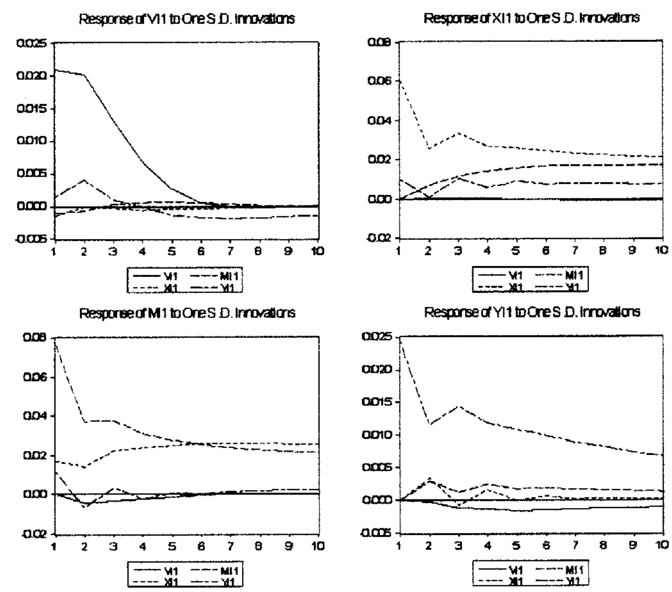
a (Taiwain)



b (Korea)



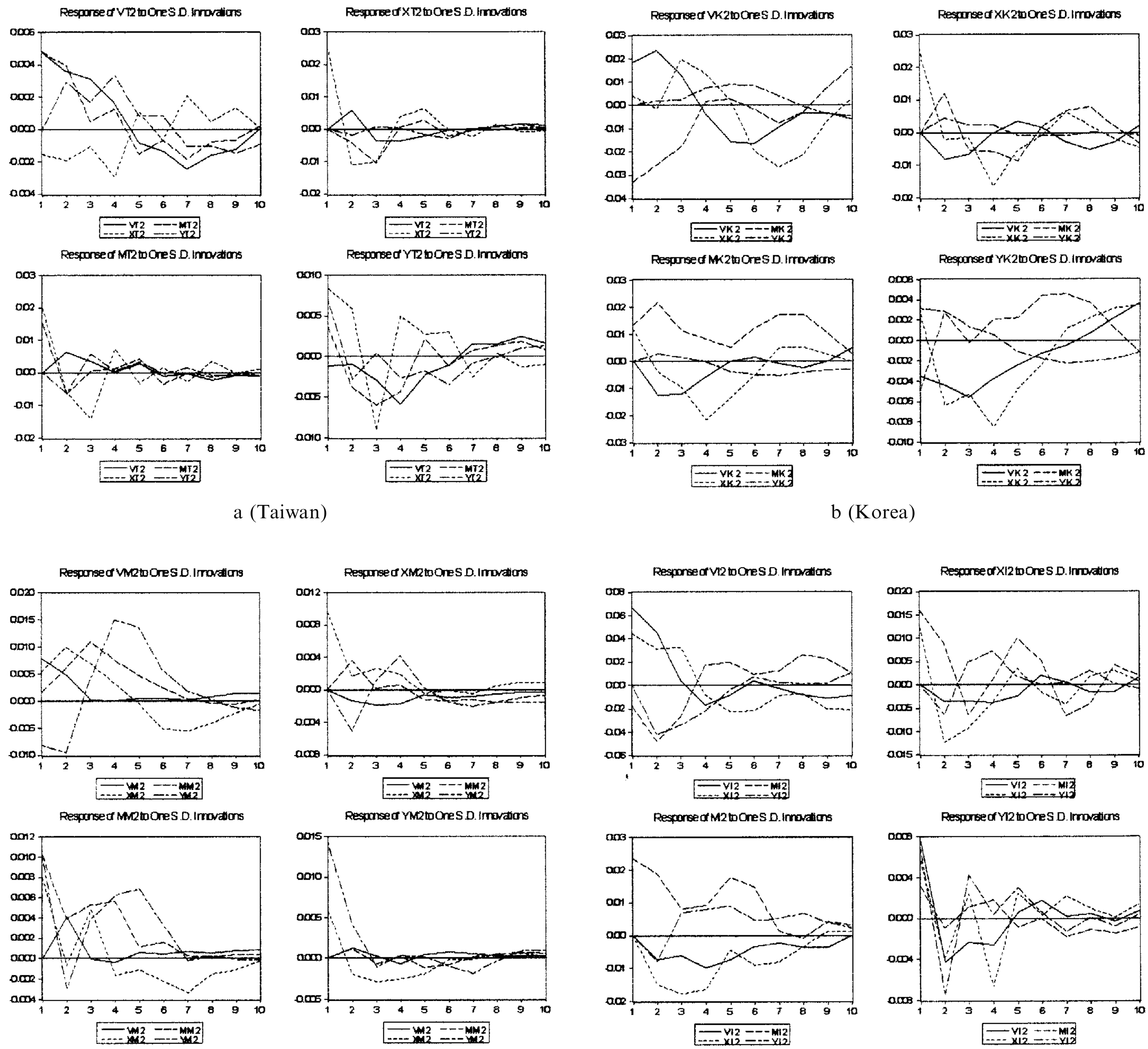
c (Malaysia)



d (Indonesia)

Figs. 1a–1d. *Impulse reponse to one SD innovation* (*pre-crisis case*)

affect the long-run equilibrium relationship among exchange rate volatility, export, import and productivity for all Asian countries considered in this paper. The results of the GC test, from pre- to post-crisis periods, show that the productivity from the relatively exogenous position became more endogenous and the exchange rate volatility became relatively exogenous for Taiwan, Korea and Indonesia. The exogeneity ordering, however, does not change too much for Malaysia (only exchange rate volatility shifts a little to precede import volume). The relative exogeneity of the exchange rate volatility after crisis implies that policymakers became more sensitive to the innovation of exchange rate volatility and the international traders were more likely to be risk-averse. Moreover, the IRs for the pre-crisis period demonstrate that the productivity had severe effects on export, import and itself for all four Asia countries considered. Export's shock played a secondarily important role, which affects the volume of export and import for countries except Korea. A surprising finding from IRs is that, before the crisis, the shock from exchange rate volatility did not yield any significant effect on export, import and productivity, which illustrates a similar result



a (Taiwan) b (Korea)

c (Malaysia) d (Indonesia)

Figs. 2a–2d. *Impulse response to one SD innovation* (*post-crisis case*)

as from the GC test. Exchange rate volatility's shock merely affected itself in the short-run and died out gradually. However, for the post-crisis period, oscillatory paths around zero of the IRs imply the dynamic effects among variables, which assert an ambiguous finding for the direction of effect and the relative importance (exogeneity) among these variables. This ambiguous finding after the Asian financial crisis illustrates that international traders were more likely to be risk-averse and policymakers kept a more aggressive attitude towards the outcome of the turmoil since their control powers over variables' shocks were dampened thereafter. They kept changing their trade behaviours and shifting the economic policy decisions during the post-crisis period, and thereafter the shock from each variable to others was not firmly predicted well. Finally, the analysis of variance decomposition shows that the VDs in export for Taiwan, Korea and Malaysia, and in productivity for Malaysia and Indonesia did not change from pre-crisis to post-crisis era. However, most of the rest of the FEVs in variables were decomposed into their own innovation more proportional in the pre-crisis period than in the post-crisis period.

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